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# Decoupling in India's building construction sector

Trends, technologies and policies

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## Decoupling in India's building contruction sector?

Trends, technologies and policies

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## **Decoupling in India's building construction sector: trends, technologies and policies**

**Abstract:** India's present development trajectory is at a crucial juncture with a requirement to meet the demands of a population of over 1.2 billion along whilst ensuring environmental sustainability. The resulting economic growth over the past two decades has over-exploited finite natural resources and led to tremendous environmental degradation. Therefore, decoupling economic growth from resource consumption is crucial in the transformation towards a green economy. Building construction is one of the most resource-intensive sectors, as well as creating high impact on the environment. This study analyzes existing mechanisms in India's building construction sector that attempt to decouple economic growth from resource use and environmental impacts. The key contributors for decoupling are analyzed. Recommendations for regulatory, market incentives, transparency and data monitoring, capacity building are provided for an array of policy initiatives targetted at political and financial decision makers at the national, state and local level, for different building

**Keywords:** building materials; buildings, climate change, decoupling; energy efficiency; environmental performance targets; material flow; public policy; resource efficiency; India

## **Introduction**

The emerging wave of urbanisation in India is fuelling growth in the building construction sector. The number of towns and cities increased from 2,774 in 2001 to 7,935 in 2011 (Census of India, 2011). The 2011 census indicates approximately 370 million people or 31.20% of the total population live in urban areas, which is an increase of 3.35% since 2001. The affordable housing deficit in urban areas already stands at approximately 19 million units (MHUPA, 2012) and an additional 28 million units are required by 2022 (KPMG, 2014). To meet the increase in demand, the total floor area of buildings is projected to increase fivefold, from approximately 1,940 million m<sup>2</sup> in 2005 to about 9,675 million m<sup>2</sup> in 2030, with residential buildings occupying about 67%, followed by commercial buildings (19%), hospitality sector (8%) and retail (6%) (Climate Works Foundation, 2010). Development and welfare programmes of the Government of India such as Housing for All, Smart Cities Mission and the Atal Mission for Rejuvenation and Urban Transformation (AMRUT) aim to meet this demand and will also enhance growth in the building construction sector.

Buildings impose a substantial stress on the country's finite resources by giving rise to the consumption of raw materials for construction and fossil fuel for energy. In addition, buildings impose considerable impact on the environment leading to loss of bio-diversity, air and ground water pollution, greenhouse gas emissions (GHG), etc. at various stages of the building life-cycle. Despite these adverse effects, growth in this sector is inevitable to meet the demand and also to contribute to the economic growth of the country. For the period of 2016-2017, the construction sector (including non-building construction) contributed to approximately 8%. Of the total electricity consumption in the country during the year 2015-2016, 24% was consumed by the

residential sector and 9% by the commercial sector, taking total consumption by building-related uses to approximately 33% (CSO, 2017). Moreover, it is estimated that a growth rate of approximately 6% in total energy use from all sources is needed to sustain a growth rate of 8% in Gross Domestic Product (GDP) (Planning Commission, 2013a). Therefore, an urgent need exists to decouple economic growth from resource consumption (as much as possible) and environmental impact for promoting sustainable growth. Decoupling is identified as a key strategy for creating a green economy that has now become imperative throughout the world.

This paper analyses decoupling resource consumption and environmental impacts from growth in the Indian building construction sector. The paper is structured as follows. First, as a part of this introduction, the concept of decoupling is explained. This is followed by an analysis of India's commitments to Paris Agreement (United Nations Framework Convention on Climate Change (UNFCCC)) along with other major national missions for their overall relevance and contributions towards decoupling in the building sector in India. In the subsequent sections the methods are explained; trends in decoupling and technologies and policies that contribute to decoupling are analysed based on the methodology; and a policy gap analysis is conducted and key recommendations are made.

### ***What is decoupling?***

Decoupling can be defined as the process of removing the link between any two variables. Decoupling can be classified into the following two categories as per the International Resource Panel (IRP) (UNEP, 2011):

- *Resource decoupling*: This means reducing the use of (primary) resources whilst the economy grows. This understanding of ‘dematerialization’ is based on the concept of using fewer resources such as raw materials, energy, water and land to achieve the same economic output, resulting in more efficient use of resources. For example, the use of hollow bricks in construction has been steadily increasing in India. These bricks utilise 25-60% less raw materials (primarily soil) due to the cavities within them. Although their compressive strength is less than solid burnt clay bricks, it is still sufficient to meet the Indian Standard code requirements for a framed construction and hollow bricks also offer better thermal insulation. In this way primary resource use decreases without a drop in productivity.
- *Impact decoupling*: This means reducing the negative environmental impacts that arise from the extraction of resources (e.g., degradation of rivers and land caused by extracting sand and soil respectively), production (e.g., land degradation, waste and emissions), use of commodities (e.g., energy/transport resulting in CO<sub>2</sub> emissions), and in the post-consumption phase (e.g., waste and emissions) per unit economic activity (e.g., GDP and GVA). The use of fly ash bricks in construction is an example of impact decoupling. Fly ash, a by-product of steel and thermal power plants, is used in place of soil as a primary raw material for making bricks. Relatively little electricity is used to operate the equipment in the manufacture of fly-ash, whereas conventional brick kilns are biomass/coal-fired which consumed higher amount of fuel. This reduces the environmental impacts caused by soil extraction such as loss of fertile topsoil, air pollution caused by brick kilns, as well as the air and ground water pollution

caused by dumping fly-ash into fly-ash ponds or landfill. Resource substitution can effectively decrease the high environmental impact through the deployment of an environmentally efficient alternative.

In addition, decoupling is also expressed as absolute/strong and relative/weak (Handrich et al, 2015; Jackson, 2017). Absolute/strong decoupling is the reduction in total resource use or environmental impact whilst the economy grows. Relative/weak decoupling is the reduction in the intensity of resource use or environmental impact, *i.e.*, reduction in resource consumption or environmental impact per unit of economic activity. Both resource and impact decoupling can be empirically either strong or weak.

On a macro-economic scale strong resource (particularly energy use) and impact (including GHG) decoupling on the GDP has been observed among OECD countries, with Germany leading the way. China shows signs of weak decoupling with the potential to turn that into strong decoupling in the future (DIW Econ, 2015). India is currently on course in fulfilling its pre-2020 voluntary pledge of reducing emissions intensity of its GDP by 20-25% over 2005 levels by 2020. Energy intensity of GDP (in MJ/Indian Rupee (INR)) was reduced by 41.7% between 2006 and 2016 (with a sharp decline of 35.66% between 2011-12 (see figure 1) implying the occurrence of a weak resource decoupling in terms of primary energy consumption (CSO, 2017). In the same period CO<sub>2</sub> emission intensity of GDP (kg per 2010 US\$ of GDP) has declined after hitting a peak in 2009. However, there is no definitive trend in impact decoupling that is observable (see [Figure 1](#)).

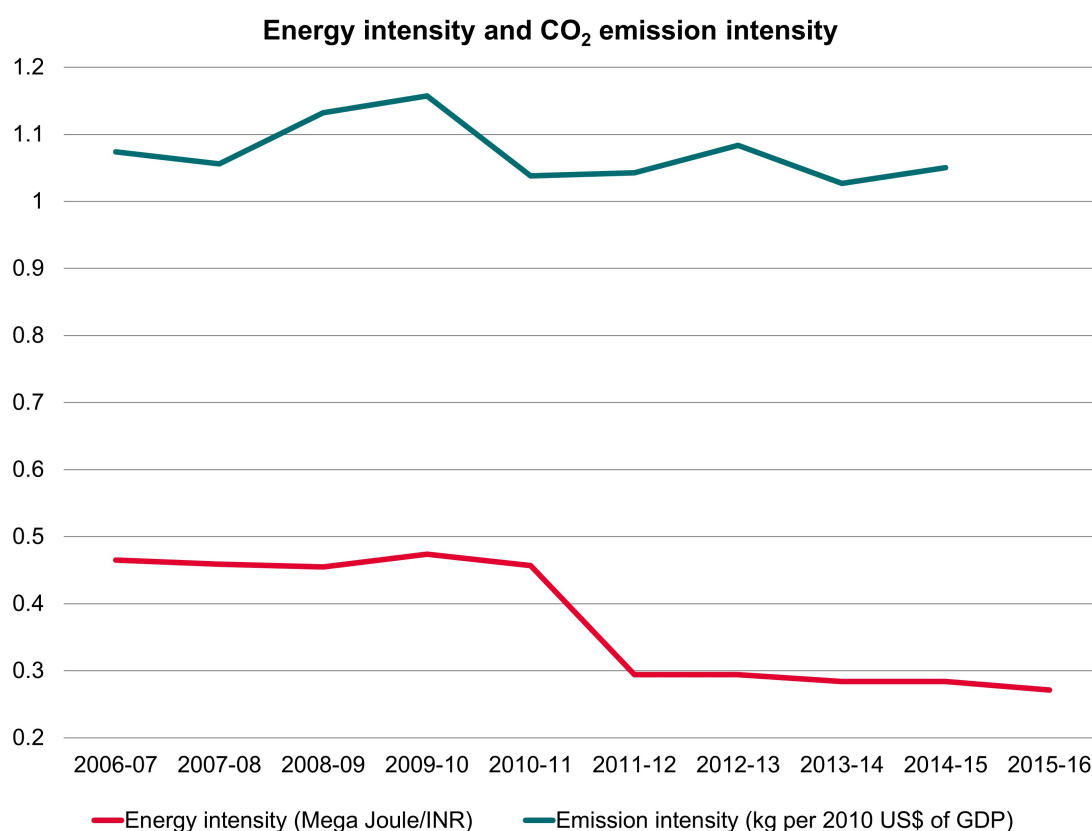


Figure 1: Year wise trends in energy intensity and CO<sub>2</sub> emission intensity in India

Source: adapted from CSO, 2017

Decoupling exclusively in the building construction sector has not yet been analysed in previous studies. However, conceptual parallels can be drawn from the literature to conduct a theoretical analysis at different phases of building construction (see Table 1).

Table 1. Key factors of decoupling at various phases of building life-cycle.

Building life-cycle phase	Key factors	
	Resource decoupling	Impact decoupling
Raw material extraction	<ul style="list-style-type: none"> <li>Energy use for extraction of materials</li> </ul>	<ul style="list-style-type: none"> <li>Biodiversity loss</li> <li>Soil erosion and land instability</li> <li>Lowering of ground water table</li> <li>Water contamination</li> <li>Air pollution</li> </ul>
Building products manufacturing and use	<ul style="list-style-type: none"> <li>Energy use for product manufacturing</li> <li>Resource use for product manufacturing</li> </ul>	<ul style="list-style-type: none"> <li>Water contamination</li> <li>Air pollution (e.g., CO<sub>2</sub>, NO<sub>x</sub>, SO<sub>x</sub>, particulate matter (PM))</li> <li>Lowering of ground water table</li> </ul>



	<ul style="list-style-type: none"> <li>• Fresh water use</li> </ul>	
Construction on site (including demolition)	<ul style="list-style-type: none"> <li>• Energy use for construction</li> <li>• Energy use for demolition</li> <li>• Fresh water use</li> </ul>	<ul style="list-style-type: none"> <li>• Water contamination</li> <li>• Air pollution</li> <li>• Lowering of ground water table</li> </ul>
Operation and maintenance (O&M)	<ul style="list-style-type: none"> <li>• Energy use for operation and maintenance</li> <li>• Fresh water use</li> </ul>	<ul style="list-style-type: none"> <li>• Air pollution (e.g., CO<sub>2</sub>, NO<sub>x</sub>, SO<sub>x</sub>)</li> <li>• Lowering of ground water table</li> </ul>

### ***Paris Agreement: implications for decoupling India's building sector***

Post 2020, the voluntary pledge of reducing emissions will be followed under the country's Nationally Determined Contributions (NDC) commitment under UNFCCC to reduce the emissions intensity of its GDP by 33% to 35% by 2030 from 2005 level (India, Lok Sabha, 2107). Some of the important measures to curb emissions from building sector include demand side management (DSM) programmes such as:

- *Residential building sector:* Deploying energy efficient LED lamps, promoting standards and labelling programme for appliances, introduction of design guidelines for energy efficient multi-storey residential buildings
- *Commercial building sector:* Energy Conservation Building Code (ECBC) which sets minimum energy standards for new commercial buildings, which has been adopted and notified by eight states

These DSM efforts are further supplemented by India's NDC to achieve 40% cumulative electric power capacity from non-fossil fuel based energy sources with an estimated energy potential of 900 GW by 2030 (UNFCCC, 2015). As a subset of this commitment, a target of achieving a capacity of 40 GW of rooftop solar photovoltaic systems (solar rooftops) has been set for buildings by 2020 (PIB, 2015). Some of the key measures taken in achieving this goal include (PIB, 2017):

- renewable purchase and generation obligations
- mandatory provision of rooftop solar and 10% renewable energy under smart cities mission
- recommendations for amendments to the local building bye-laws for the mandatory provision of roof top solar PV for new construction
- the inclusion of capital costs for roof top solar PV as a part of the total housing loan
- recommendations to make net-metering compulsory (for utility consumers who are owners of distributed generation systems)

Mitigation strategies outlined in the NDC document also focus on scaling up renewable energy production and improving transmission and distribution network. The smart cities mission is also a part of the mitigation strategies (Government of India, 2018). Other prominent national missions, the National Action Plan on Climate Change (NAPCC) of 2008 has two areas that broadly address decoupling in buildings. They are National Solar Mission (NSM) and National Mission on Sustainable Habitat (NMSH). The intent of both of these missions is in line with India's NDC to increase the share of non-fossil fuel based generation in total electric power and to reduce the carbon intensity of emissions respectively. Besides, NMSH also focus on the issue of material recycling and urban waste management. Two of components in India's NDC focus on decoupling which entail the reduction in emissions intensity and increased share of non-fossil fuel based electricity. Both these measures support impact decoupling while resource decoupling is either implicit or rather inconspicuously absent.

## Methods

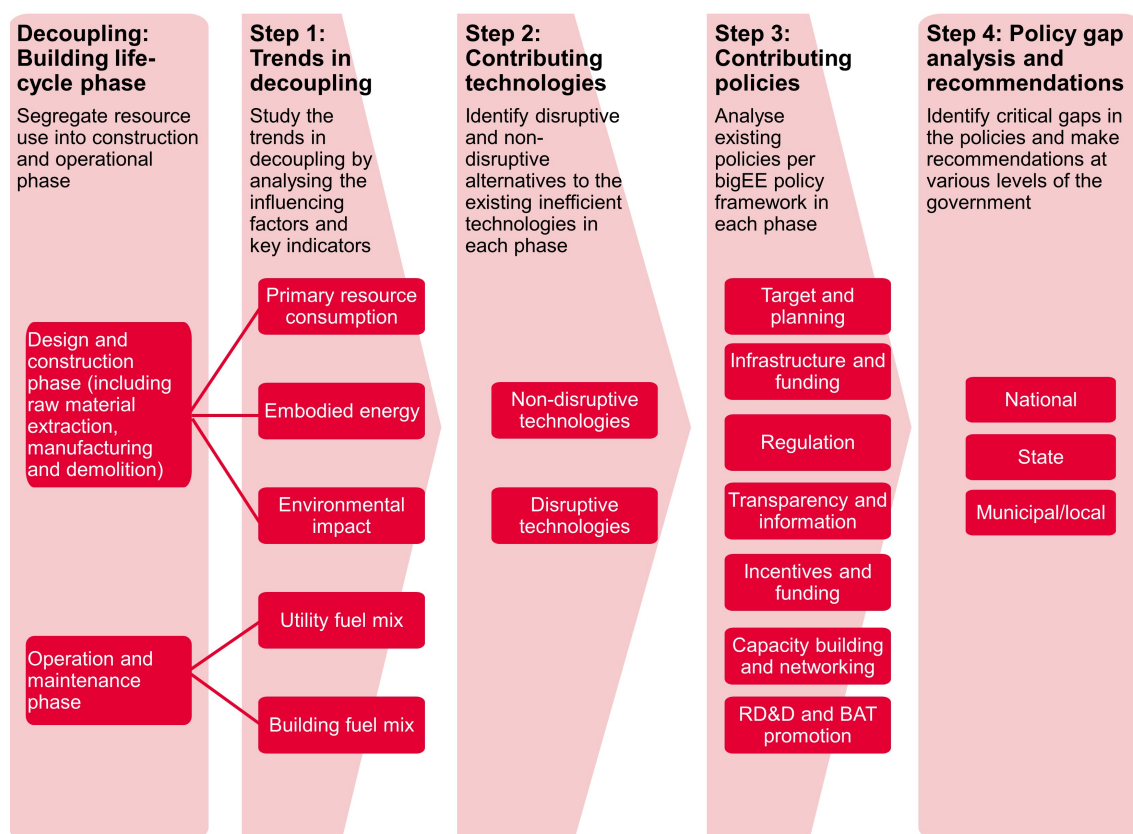
The present study analyzes decoupling in resource consumption and environmental impact in two distinct different phases i.e., design and construction phase (including raw material extraction, product manufacturing and demolition) and operation and maintenance (O&M) phase of a building life-cycle. This paper addresses decoupling in resource use and environmental impacts which are very critical. Reliable data and figures are available to make an objective analysis on decoupling based on a consistent methodology.

First, trends in decoupling are studied by analysing the influencing factors and key indicators. Second, key alternatives for the existing inefficient technologies for building construction and operation that would contribute to decoupling are studied under two categories: disruptive and non-disruptive technologies (see [Table 2](#)). Third, the existing policy framework that facilitates decoupling is studied and analysed based on a policy package framework proposed by bigEE.net. Several policies from the last two decades at national, state and local levels have been analysed (Caleb, et al., 2017). Each type of instrument has a certain aim, such as to disallow resource-wasting technologies, promote the most efficient ones, or stimulate innovation, etc. The impact of well-combined policies is often larger than the sum of the individual expected impact (bigEE.net, 2016). Therefore, such a policy package framework as proposed by bigEE.net has been chosen to analyse various policies for resource and impact decoupling. Finally a gap analysis has been conducted to identify the critical gaps in the existing policy framework and recommendations have been made to address the gaps at national, state and municipal/local levels. See figure 2 for an overview.

[Table 2: Classification of non-disruptive and disruptive technologies](#)

Non-disruptive technologies	Improving the efficiency of production and operation of existing construction practices and technologies. For example, using more efficient air conditioners, lighting and appliances in the place of old and inefficient ones, or using bricks produced from vertical shaft brick kilns (VSKB), which are more efficient than conventional kilns.
Disruptive technologies	Replacing existing production, and construction practices, and technologies with new and efficient ones. For example, replacing burnt mud bricks with fly ash bricks and autoclaved aerated concrete (AAC) blocks; using construction and demolition (C&D) waste based aggregates in place of natural aggregates; using solar cooling technologies in place of conventional air conditioning etc.

Figure 2: Steps to evaluate decoupling in India's building construction sector: trends, technologies and policies.



Source: authors' analysis

## Analysis and results

### *Decoupling during design and construction phase*

Understanding the criticality of resources on the basis of the triple bottom line impacts, *i.e.* economic, social/cultural and environmental viability, provides the foundation for

identifying resource synergies and assessing and addressing the conflicts that may arise across sectors such as construction, agriculture, industry etc. Globally, the construction sector accounts for 30-40% of all material flows. Resource-efficient measures hold significant material-saving potential of more than 40%. About 50 billion tonnes of materials could be saved if all the housing demand were constructed using resource-efficient options by 2030 (IGEP, 2013). This also holds true for a rapidly developing country like India. Materials and products such as cement, concrete, steel, bricks and tiles, sand and aggregates, fixtures, fittings, paints and chemicals, petrol and other petro-products, timber, minerals, aluminium, glass and plastics account for nearly two-third of construction costs (Planning Commission, 2013b).

#### *Trends in resource use and impact: is there decoupling?*

##### Resource decoupling

Trends in decoupling for construction materials (all types of construction activities) can be seen in [Figure 3](#) for the period of 2011-12 till 2015-16. All values of input, output and GVA are at constant 2011-12 prices in million INR. The data on materials used exclusively for the construction of buildings is not available. However, unlike cement and steel, bricks and tiles are used in large quantities in building construction and can be taken as a proxy data for building construction. The use of bricks has consistently increased except for a dip in 2013-14. Therefore, for the sake of simplicity it can be assumed that other resources used for building construction have also followed similar pattern.

The GVA is taken as an indicator of growth in the construction sector (all types of construction activities). It has consistently increased from 77,733.4 million INR from

2012-13 to 82,543.1 INR in 2015-16. However, GVA exclusively due to the construction of buildings is not available. The input value at constant prices of different materials represents a proxy for quantities of materials used in construction. Material use in the construction sector in India has been on the rise since 2011-12 with a slight dip in 2012-13 for iron and steel and in 2013-14 for cement, brick and tiles. This implies an absence of absolute resource decoupling. Further, material intensity (for total construction), represented by the ratio of total input value (i.e., material use) to the GVA has been increasing with a slight dip in 2013-14 indicating an increase in the material use intensity. Broadly, output value from non-residential buildings has been increasing while that of the residential buildings has been decreasing. Therefore, there are no apparent signs of weak resource decoupling in terms of materials use.

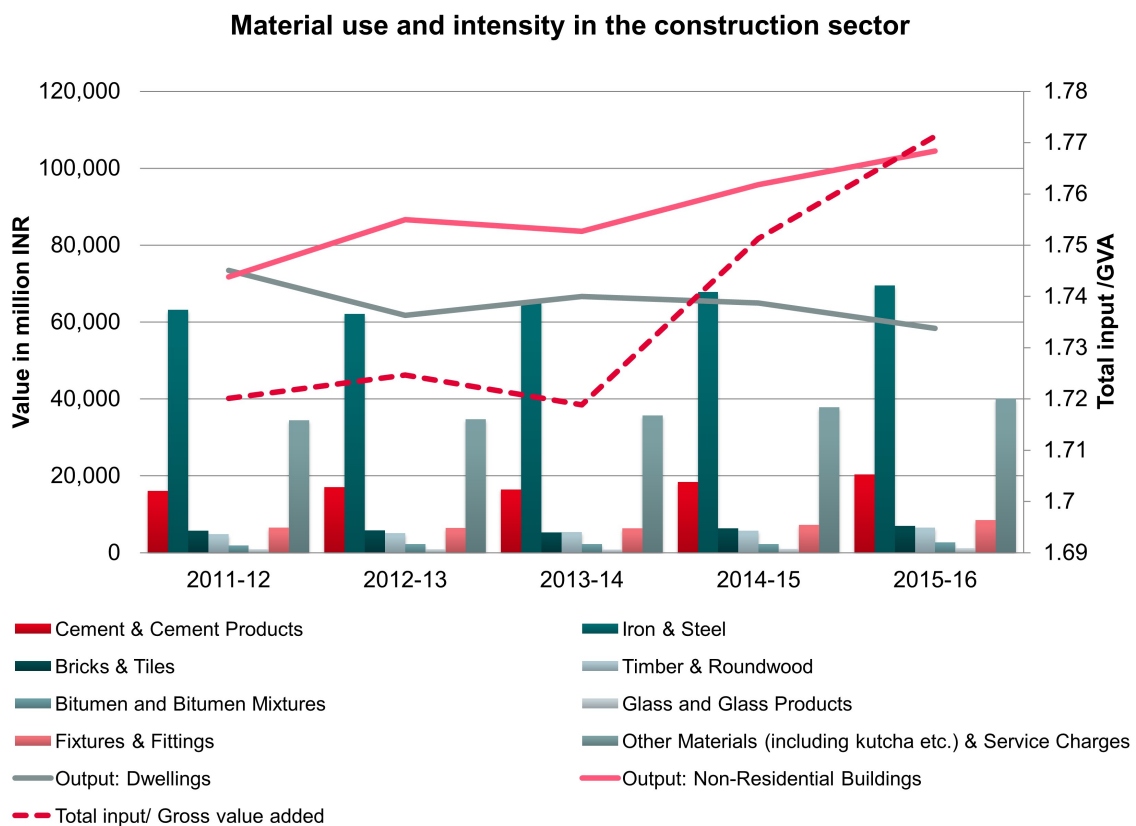


Figure 3: Material use and intensity of building construction materials.

Source: adapted from MOSPI, 2018a

## Impact decoupling

Since the environmental impact of materials varies in terms of their nature and metrics, aspects related to impact decoupling are discussed below along with the contributing technologies.

### *Contributing technologies for decoupling*

Compared to bulk materials *e.g.* cement (lime stone), steel, bricks (soil), and fine (sand) aggregate, all other materials are not used in large quantities in a building, but have a higher cumulative cost as compared to bulk materials such as bricks, cement, mortar etc. (see Figure 3). Therefore, contributing technologies, impact decoupling, and policies for decoupling in these four materials has been studied further.

### Cement and steel

Portland Pozzolana cement (PPC) utilises about 30% less limestone than ordinary Portland cement, which is a valuable contribution to resource as well as impact decoupling (limestone as a resource and environmental impact of mining limestone, as well as, reduce the clinker production needed). The cement industry has already shifted towards fly ash based PPC. PPC's share in total cement production in India is estimated to be 67% (Rajya Sabha Secreteriat, 2011). Steel used as bars and rods in the construction sector is 100% recycled in the secondary market after buildings have been demolished and thus contributes towards decoupling in terms of environmental impact by avoiding the use of raw ore, as well as, contribute towards reducing energy use

associated with producing primary steel.<sup>1</sup> The Indian steel industry has adopted best practices and reduced the specific energy consumption of primary steel production from 8-9 Gcal/tcs (tonnes of crude steel) in 2004 (Thakkar, 2008) to 6-7 Gcal/tcs in 2015 (Ministry of Steel, 2015), thus supporting impact decoupling in terms of embodied energy. Perform Achieve and Trade scheme, a regulatory instrument to reduce specific energy consumption in energy intensive industries, has been very instrumental in increasing energy efficiency in steel and cement sectors (BEE, 2015). However, there is further scope for improvement as the global best practice for steel sector's specific energy consumption is around 3.3 Gcal/tonne. The sector could also improve in terms of water consumption, land resourcefulness and reducing pollution (CSE, 2018).

#### Bricks and sand

The use of burnt clay bricks for construction has been a common practice in India. According to the Ministry of Mines, Government of India, brick earth accounted for 5.2% of total minor minerals extracted in the year 2014-15. The extraction of brick earth involves removing topsoil, which is valuable for its high level of fertility and has high opportunity costs because of its use in agricultural production. In addition, brick kilns use coal and biomass for the burning of bricks, which leads to air pollution. While improving the efficiency of conventional brick kilns can be considered non-disruptive alternative, fly-ash bricks and AAC can be considered disruptive alternatives to burnt clay bricks (see [Table 3](#)). In the year 2014-15, 184.14 million tonnes of fly ash were generated by 145 thermal power plants (Central Electricity Authority, 2015). Disposal of this material has been a major problem in India, but it has started to be incorporated

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<sup>1</sup> Based on the authors' survey in 10 Indian cities



into a variety of masonry units in the construction sector. It is used both as a stabilizer and as a main component in bricks. Since it is a by-product, the energy used and CO<sub>2</sub> emitted in its production are attributed to the intended product and not to the production of fly ash. Thus, the utilization of fly ash in brick-making results in impact decoupling, since not only is the extraction of topsoil reduced, thereby reducing the environmental impact of extraction, but also the energy required to produce these bricks is lowered. As per estimates by the Fly-Ash Bricks and Blocks Manufacturers' Federation (FABMAFED), about 20 billion ft<sup>3</sup> (0.566 billion m<sup>3</sup>) of topsoil could be saved annually if the existing 140,000 red brick kilns in the country switched to using fly ash. Over the last two decades, the production of fly ash-based bricks/blocks/tiles has increased from 0.70 million tonnes in 1998-99 to 12.02 million metric tonnes in 2014-15, which constitutes 11.72% of total fly ash utilized in that year (Central Electricity Authority, 2015). Existing green building rating systems in the country mandate the use of fly ash in construction. However, fly ash availability and supply varies from region to region. A regional approach based on fly ash availability may be a more prudent way to mandate its use in construction. Although embodied energy of AAC is higher compared to clay bricks and fly-ash bricks, they have a better thermal conductivity value which helps lowering the cooling load of buildings during O&M phase. Overall, it can be said that brick industry in India is on the path to achieve impact decoupling in terms of conserving topsoil, addressing fly-ash disposing problem and also in lowering embodied energy of bricks (as the production of AAC becomes more efficient).

**Table 3: Comparison of properties of various alternative masonry materials**

Parameters	Clay bricks	Autoclaved aerated concrete (AAC)	Fly ash bricks

CO <sub>2</sub> emissions (kg CO <sub>2</sub> /kg of brick)	0.2 <sup>c</sup>	0.3 <sup>e</sup>	0.04 <sup>b</sup>
Embodied energy (MJ/kg of brick)	3 <sup>c</sup>	3.5 <sup>e</sup>	0.52 <sup>b</sup>
Thermal conductivity (K value) W/m-K	0.7 <sup>c</sup>	0.12 <sup>a</sup>	0.6-0.8 <sup>c</sup>
Soil consumption	1 kg/kg of brick <sup>d</sup>	0 kg/kg of brick	0 kg/kg of brick

<sup>a</sup> Satyanarayan, 2014

<sup>b</sup> Flyashbricksdelhi, 2010. Weight of fly ash bricks considered to be 2.5 kg per brick

<sup>c</sup> Based on expert consultation

<sup>d</sup> Based on expert consultation

<sup>e</sup> Kumar, Buddhi, & Chauhan, 2012

## Sand

Sand continues to be a critical resource for construction; it contributed 16.5% to the value of minor minerals in 2014-15 (Ministry of Mines, 2015). The demand for sand as a construction aggregate accounted for 29% of the total aggregate demand in 2010.

According to a study by the Freedonia Group, the total demand for sand is expected to increase from 630 million metric tonnes in 2010 to 1,430 million metric tonnes in 2020 (Aggregates Business Europe, 2013). Sand mining has adverse impacts on the environment, which include degradation of land, disturbance to the water table resulting in topological disorder/erosion, changes in biotic-and abiotic systems, severe ecological imbalance etc. (O.C. & Ramzan, 2016). In this context, viable alternatives have been developed with stable physical and chemical properties making it stronger than natural sand. One of the alternatives used in building construction is manufactured sand (M-sand). Manufactured sand or M-Sand is defined as a purpose made crushed fine

aggregate produced from suitable source materials. Most commonly M-sand is made by crushing natural stone, to get artificial sand of desired size and grade which is free from impurities (Shanmugapriya & Uma, 2012). However, as is the case of natural stone quarrying, the environmental impact of M-sand is considerably higher if not similar than of extraction of natural sand from the riverbeds. From experimental results it has been proved that M-Sand can be used as partial replacement for the natural sand, and the compressive and flexure strengths are increased as the percentage of M-Sand is increased up to optimum level (Shanmugapriya & Uma, 2012). Due to the increased level of construction, demolition waste is also on the rise. Recycled coarse aggregate is made by crushing the waste concrete of laboratory test cubes and precast concrete columns (Kabir, Al-Shayeb, & Khan, 2016). In India, particularly in the state of Karnataka, M-sand has been included in the Schedule of Rates for public works with close to 100 M-sand manufacturing facilities located in the state (Govind, 2015).

#### *Policies for decoupling*

Resource interventions that have been recognized as crucial to enabling decoupling in the buildings and construction sector were analysed (see [Figure 4](#)). Regulatory policies appear to be the front-runner when it comes to resources, followed by transparency and information, target-setting and-planning, and infrastructure and funding. Research, Development and Demonstration (RD&D) and best available technology (BAT) promotion and capacity building appear to be severely underrepresented in policies. Although the four resource options are covered by regulatory oversight, implementation is possible only in formal sectors such as cement and steel. It is important to note that sand and soil often operate outside of the formal economy and run-the risk of slipping through the net. Capacity building and R&D policies should be encouraged.

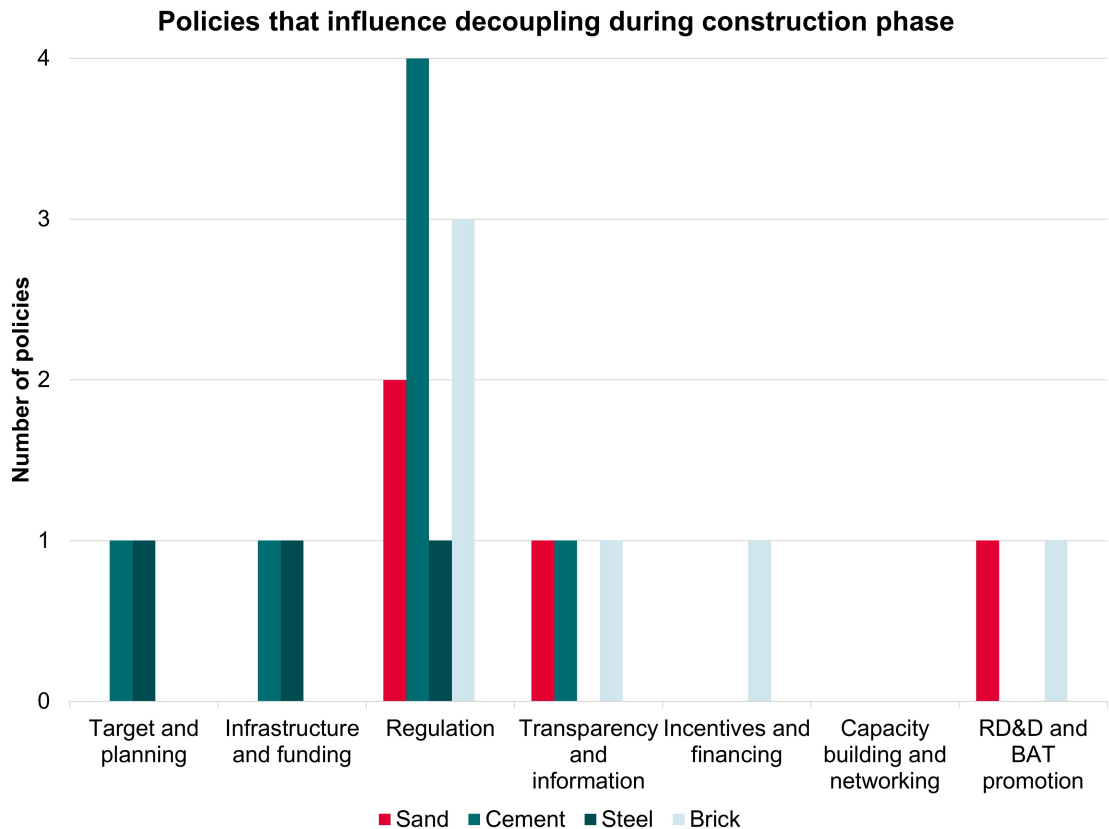


Figure 4: Policies that influence decoupling during construction phase through key materials. Source: authors.

### *Decoupling during operation and maintenance phase*

Energy consumed for the day-to-day functioning of buildings, mostly electricity, form the major component of resource consumption in the O&M phase. Since thermal power plants produce the major share of electricity in India (see Figure 8), the resulting GHG have significant impact on the environment. The energy use in the building sector in India is projected to increase over the coming decades due to the growth in population access to modern energy, and ownership of appliances as income levels rise.

Urbanisation has improved access to energy, but lack of planning has resulted in inefficient patterns of energy use (OECD and IEA, 2015). Figure 5 shows percentage of energy consumption for various end uses in residential buildings (left) and non-

residential buildings (right). Energy consumed by these different end uses varies by appliance ownership, especially air conditioner, usage, and household income. Energy consumed during the operational phase accounts for 80-90% of total primary energy use by air-conditioned residential buildings (service life of 75 years) (Ramesh, Prakash, & Shukla, 2013) and decreases to about 40-50% in the case of non-air conditioned residential buildings (service life of 50 years) (Praseeda, Venkatarama Reddy, & Mani, 2016).

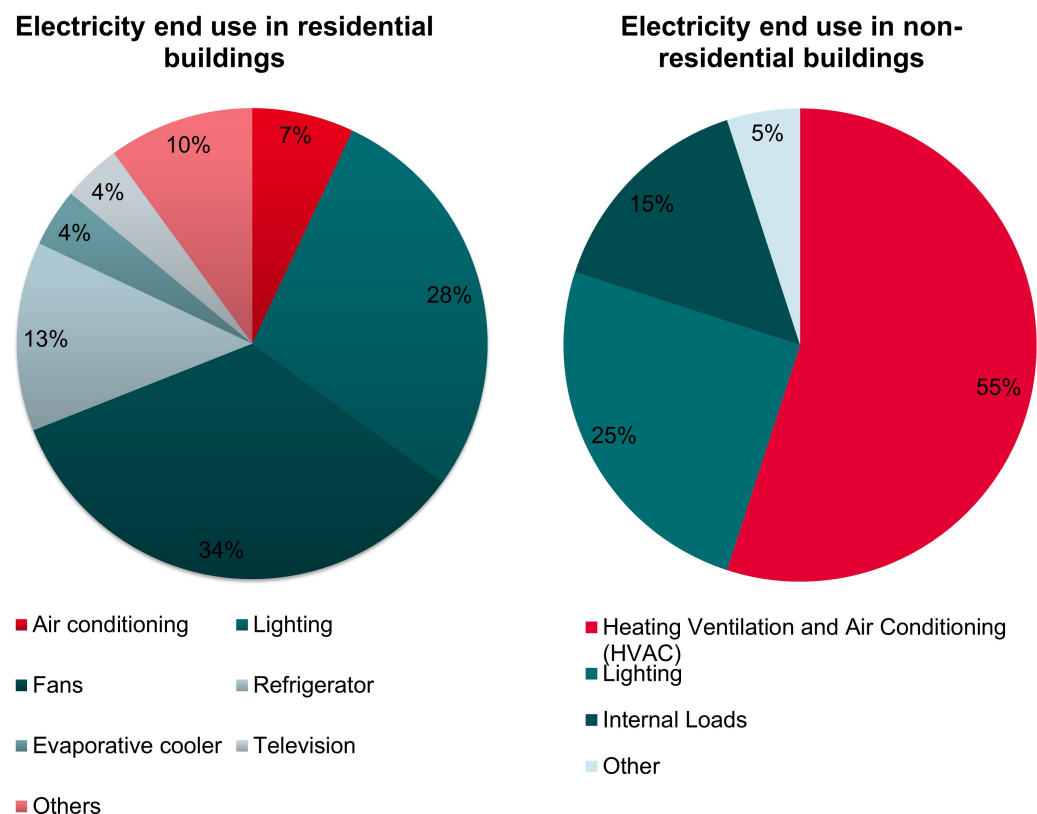


Figure 5. Electrical energy end use in residential buildings (Left); in commercial buildings (Right).

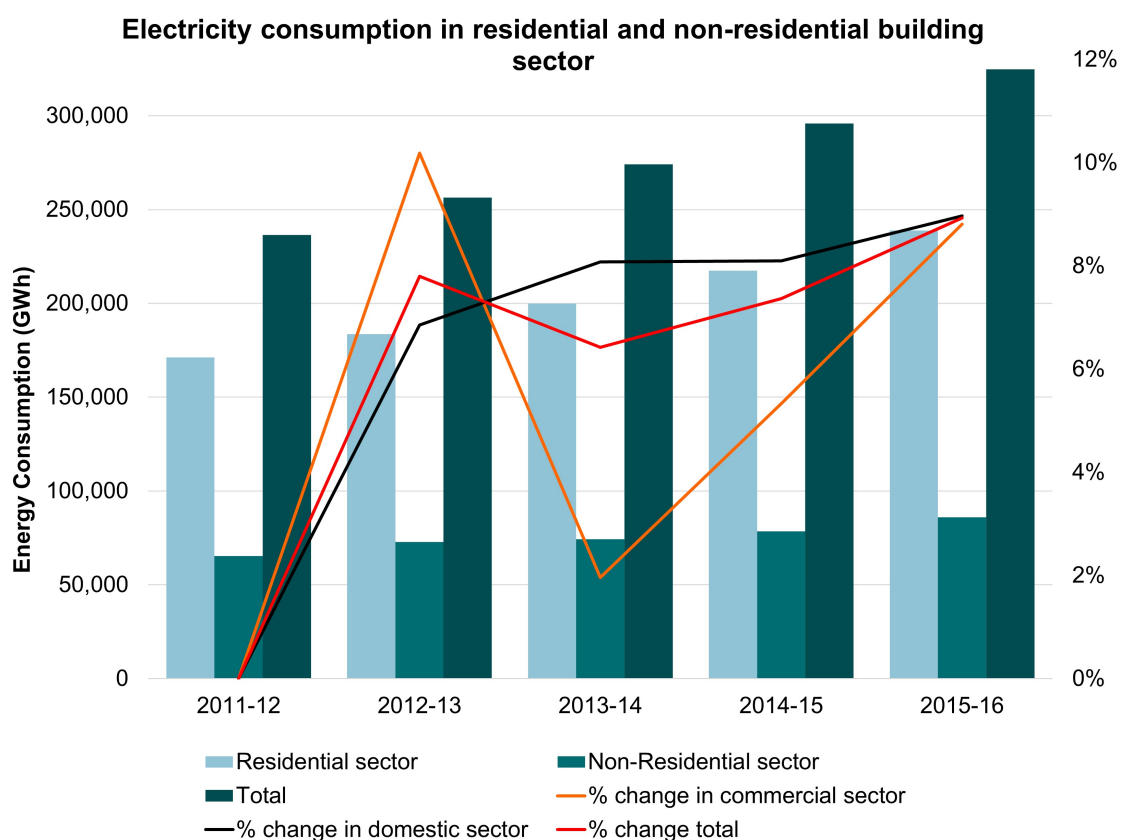
Source: left-Climate works foundation (2010), right-Planning Commission (2014)

## *Trends in resource use and impact*

### Resource decoupling

Electricity consumption has continuously increased in the past five years with a growth dip of 2% in the residential sector and 8% in the commercial sector in 2013-14

indicating an absence of strong resource decoupling in terms of energy use (see [Figure 6](#)).



[Figure 6](#). Electricity consumption and percentage increase in residential and commercial sectors.

*Source:* CSO, 2017

Energy intensity in the building sector is measured in terms of electricity consumption (GWh) per GVA (in million INR at 2011-12 constant prices) by all building related

service based activities for residential and commercial sector. GVA by households has been taken as from sequence of accounts-households (MOSPI, 2018b). The GVA for services considered under commercial sector where the consumption of energy in buildings is critical for their functioning and revenue generation are mentioned below<sup>2</sup> (MOSPI, 2018c):

- Administrative & support service activities and other professional services
- Professional, scientific & technical services including R & D
- Information and computer related services
- Education
- Health & social work
- Arts, entertainment and recreation
- Hotels and restaurants
- Trade and repair services

Overall electrical energy intensity shows a declining trend, especially in commercial building sector (see [Figure 7](#)). This is expected because of an increasing share of service sector in the country's GVA. India's service sector, consisting of buildings such as Information Technology, Business Processing and Outsourcing, finance and hospitality etc. is the second fastest growing in the world (Bhargava, 2014). Therefore, energy productivity and energy efficiency are both crucial aspects to fuel growth in this sector

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<sup>2</sup> This list is only indicative to support this study's methodology in the absence of service sector data specific to energy consumption in buildings

while fulfilling India's NDCs. A decisive trend towards weak resource decoupling in terms of energy can be observed in commercial building sector. On the other hand, the residential sector follows an opposite trend where electrical energy intensity has been increasing. This could be due to factors such as increase in the number of electrified households, in the penetration of electrical home appliances, etc. Overall, building sector shows signs of weak resource decoupling in terms of energy.

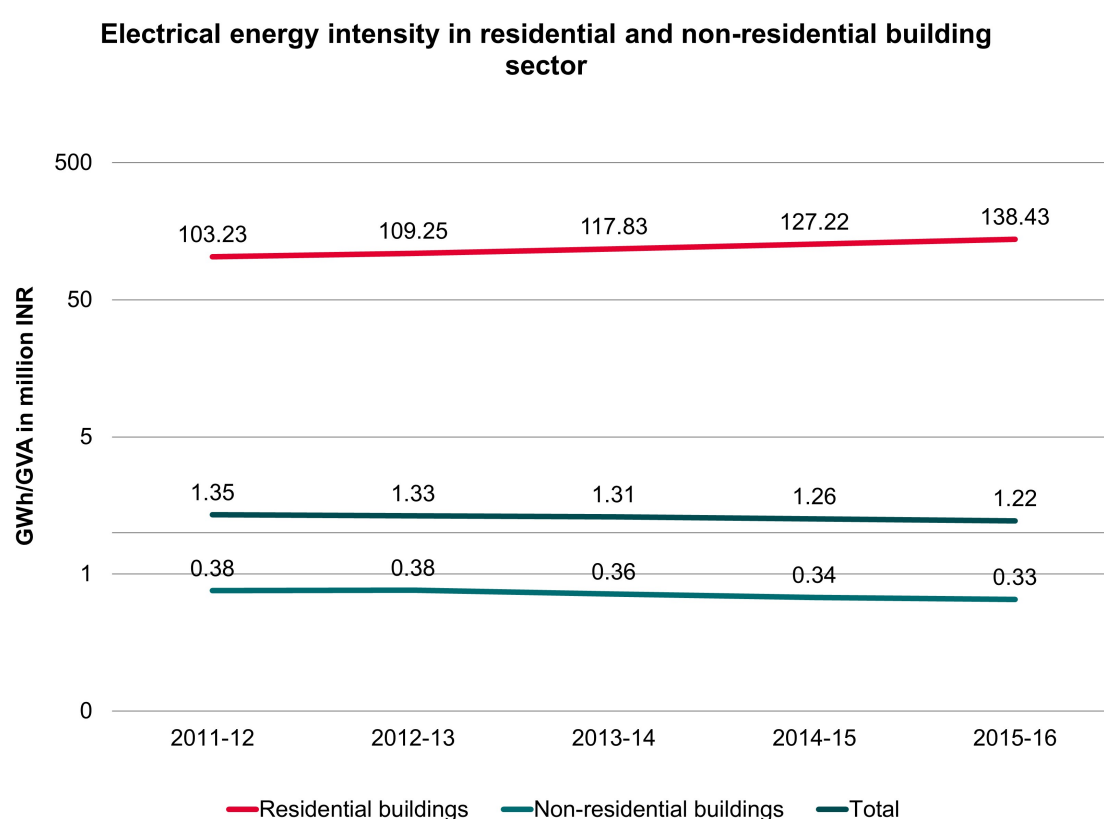


Figure 7: Electrical energy intensity in the building sector.

*Source:* adapted from MOSPI, 2018a, 2018b, 2018c

## Impact decoupling

Increase in the share of non-fossil fuel based electricity generation in the total energy mix as well as the use of on-site renewable energy in buildings will help in reducing the



GHG emissions and are key factors that contribute to impact decoupling in O&M phase.

Overall share of non-fossil fuel based electricity generation to the total electricity generation has been in decline for the past five years indicating an absence of strong impact decoupling in terms of GHG emissions (see [Figure 8](#)). It can be noticed that although the share of generating capacity of solar rooftops compared to that of the total solar renewable energy (including utility scale generation) has been on the rise, it is woefully short (approximately 96%) of the goal of achieving 40 GW of solar rooftop by 2022.

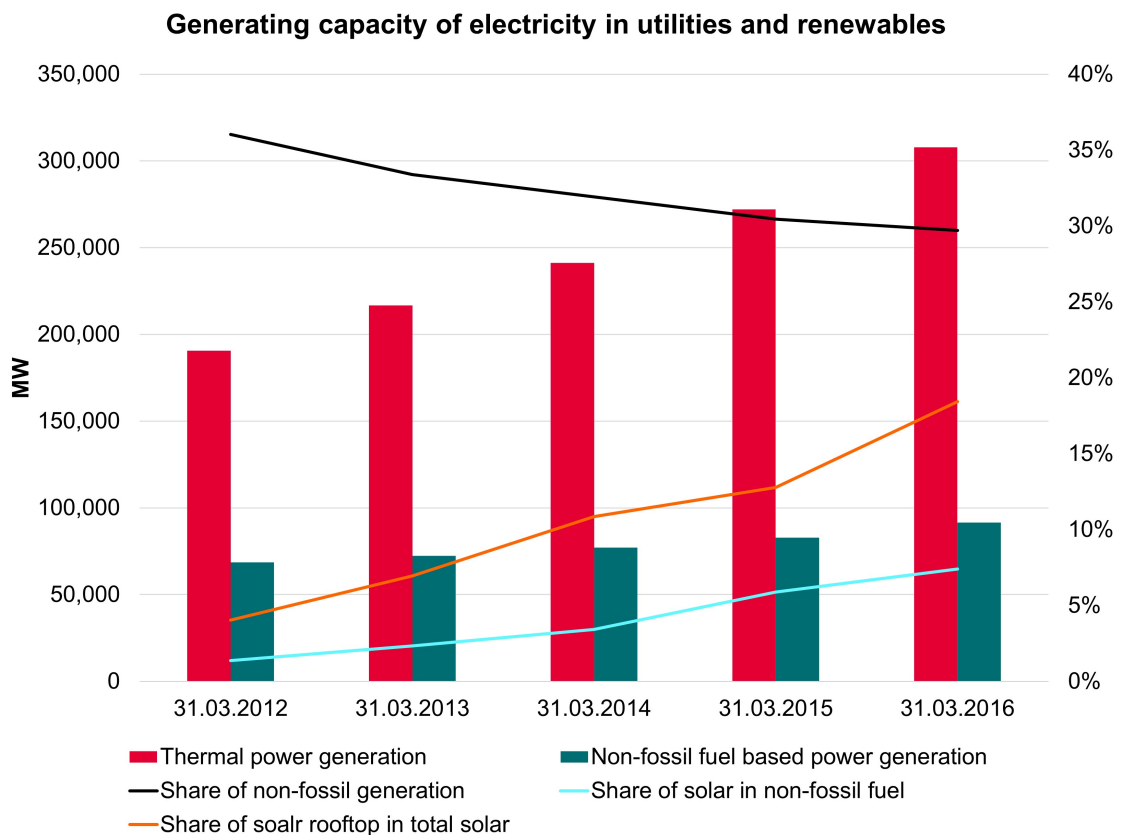


Figure 8: Generating capacity of electricity through utilities and renewables.

Source: adapted from MOSPI, 2018d

### *Contributing technologies for decoupling*

Energy efficiency and increase in renewable energy generation are often identified as key contributors to decoupling during O&M phase. Various disruptive and non-disruptive technologies have been developed to address these aspects. Non-disruptive technologies such as energy efficient building envelope; energy efficient conventional air conditioners (ACs), chillers, fans, lights, and other appliances, especially those under the ambit of Bureau of Energy Efficiency (BEE) star rating, increase the overall system and operational efficiency and thereby reduce energy consumption. Non-conventional and renewable energy technologies, such as solar cooling, and combined heating, cooling and power (CHCP) can be considered as disruptive technologies which introduces an entirely different technology option. Since space cooling constitutes one of the highest energy end-use, examples from this sector have been discussed further to illustrate the potential and limitations of various disruptive and non-disruptive technologies. This is followed by discussion on the state of building integrated renewable energy technologies.

Adopting passive building techniques is considered the first step in reducing space cooling energy demand. However, a wide range of reasons such as air pollution, noise, building usage patterns, user behaviour etc. limit the adoption of most simple passive building techniques such as natural ventilation, night purge cooling etc. Active integration of passive and active cooling systems to work in a mixed-mode/hybrid system is also still limited to demonstration/experimental buildings and still needs validation and adoption. It is prudent to assume that the majority of energy efficient projects use low hanging non-disruptive technologies that aim for component, systems and operational efficiency of the building envelope and the conventional heating,

ventilation, and air conditioning (HVAC) systems. The potential cooling generation from non-disruptive technologies currently meet miniscule percentage of space cooling energy demand. For example, as per an estimate by GIZ, even though the potential for building-integrated gas-based CHCP systems is approximately 6 GW their application in space cooling is not widespread compared to its industrial applications (Pales & West, 2014). Similarly, the total area occupied by collectors for concentrated solar heating technologies under the UNDP-GEF project on concentrated solar heat (CSH) was 16,373 m<sup>2</sup>, of which 11,247 m<sup>2</sup> (69%) were used for process heat or cooling<sup>3</sup> (MNRE, 2017). Moreover, it is difficult to integrate these technologies into existing buildings. Despite their attractive payback periods, the use of disruptive cooling technologies is still confined to a few flagship projects, owing to factors such as the scale of the project, space cooling and heating demand and schedule, technical feasibility, available expertise, and capital cost etc. (Pales & West, 2014).

Building-integrated renewable energy has a significant potential for reducing fossil fuel-based primary energy consumption in the residential building sector, however, subject to constraints such as the available roof area, electricity usage, etc. (Ramesh, Prakash, & Shukla, 2013). The proliferation of building-integrated solar PV systems (such as solar rooftops) and solar water heaters (SWH) has been especially encouraging, although not phenomenal. Out of the total 1,247 MW of solar rooftops installed at the end of 2016, residential buildings account for 349 MW, commercial buildings (private and government) for 474 MW, and the remaining 424 MW is on industrial rooftops (Bridge to India, 2017). In 2012 only a tiny fraction of energy consumption for thermal applications, about 0.25% (0.6 Mtoe out of a total of 240

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<sup>3</sup> Includes both heating and cooling. Exact estimates of space cooling are not available.

Mtoe) came from solar thermal. Looking on the bright side, residential and non-residential buildings accounted for about 97% of installed solar thermal capacity of 5.8 GW<sub>th</sub> in the country in 2014 with SWH technologies (Greentech Knowledge Solutions Pvt. Ltd, 2015). The market for SWH in buildings is expected to grow tenfold between 2014 and 2032 equivalent to the annual electricity generated from approximately 64 GW<sub>p</sub> of solar PV installations.

### *Policies for decoupling*

Policy analysis shows technological interventions that have been targeted to facilitate decoupling in the O&M phase. It can be seen that incentives and financing has been one of the popular policy instruments across different technologies, followed by capacity building and research, development and demonstration (RD&D) and promoting best available technology (BAT) (see [Figure 9](#)). One observation while making the classification was that most policies aim to minimise the total building energy consumption instead of focusing on sub-sector specific efficient technology option. Although the core construction practices and technologies in India appear to be similar across different subsectors (*e.g.* residential, offices, retail, hospitality, educational *etc.*), the energy consumption patterns in each of them vary considerably. Many efficient technologies that are suited for a particular type of building might not be suitable for another type of buildings. The exclusion of building sector/typology specific efficient technology options runs the risk of introducing trade-offs between different technology groups. This can exclude some efficient but disruptive technology options for various reasons such as high capital cost, lack of technical knowledge etc. For example, CHCP technologies are mostly suited for hospitality and medical facilities, where there is a simultaneous cooling and heating demand, and are less suited in residential applications.

However, low hanging non-disruptive technologies are still favoured in such facilities in the absence of concentrated efforts to promote more efficient subsector specific disruptive technologies.

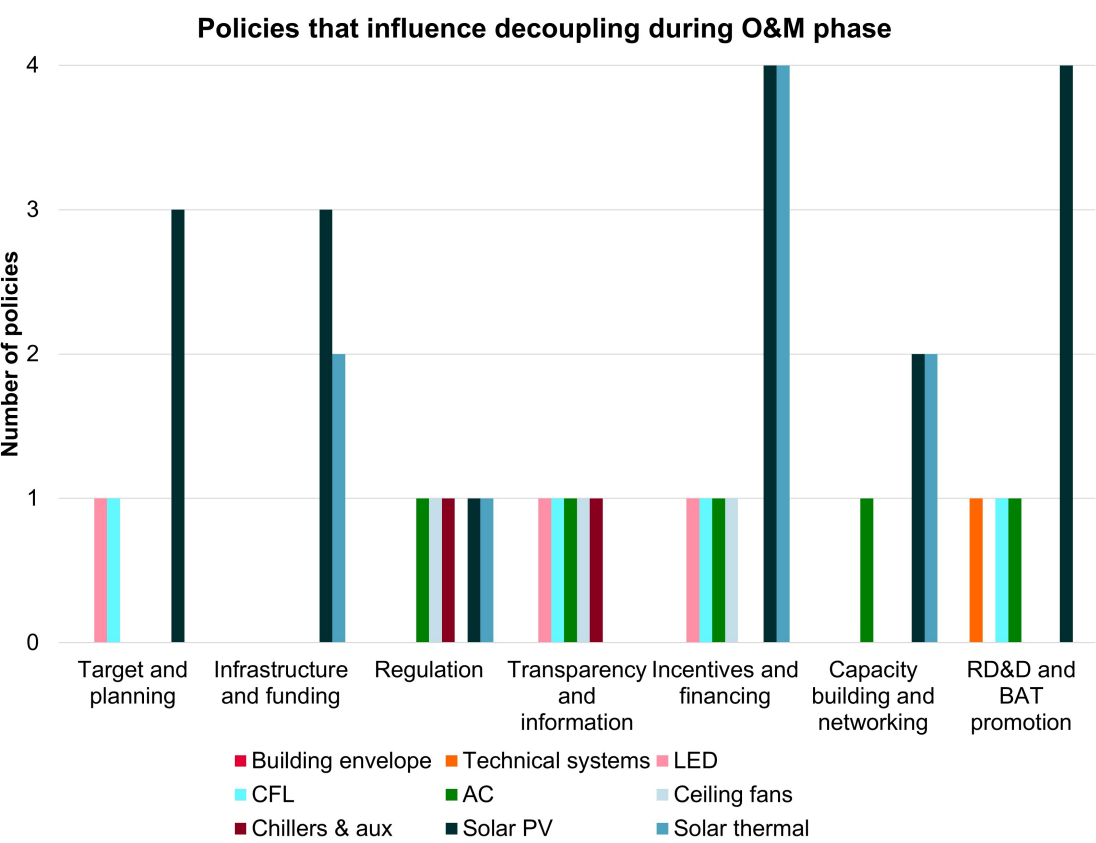


Figure 9: Policies that influence decoupling during O&M phase through key technologies.

Source: authors

Critical gaps and recommendations

Figure 10 shows the existing policy framework that has tackled the question of decoupling in the Indian building construction sector. Targets, regulation and incentives lead the way in terms of policy. Overall there are a number of incentives that are provided by the central and state governments, and financial institutions for constructing green buildings. Renewable energy is often assumed to be a subset of

energy-efficient buildings, and both the use of renewable energy and energy efficiency measures are loosely linked under the umbrella term ‘green building’. Certification schemes such as Green Rating for Integrated Habitat Assessment (GRIHA) or Leadership in Energy and Environmental Design (LEED) offer a certain level of credibility and are able to address various phases of construction holistically. However, these green building rating systems are still voluntary and there is a lack of awareness of these rating systems and the associated incentives among developers and builders, especially in small towns. Furthermore, the majority of the building projects that apply for a green rating are commercial and office buildings despite a high growth projected in residential buildings. Besides that, independent monitoring mechanism for green rated buildings is absent owing to confidentiality clauses associated with such rating systems.

Key policy gaps identified in the analysis during construction and O&M phases are described in the further subsections. Considering these gaps, key policy recommendations are listed subsequently addressing policy makers and stakeholders within building and construction sectors on national, state and local levels. They are categorized into targets and regulations, market and incentives and data and monitoring.

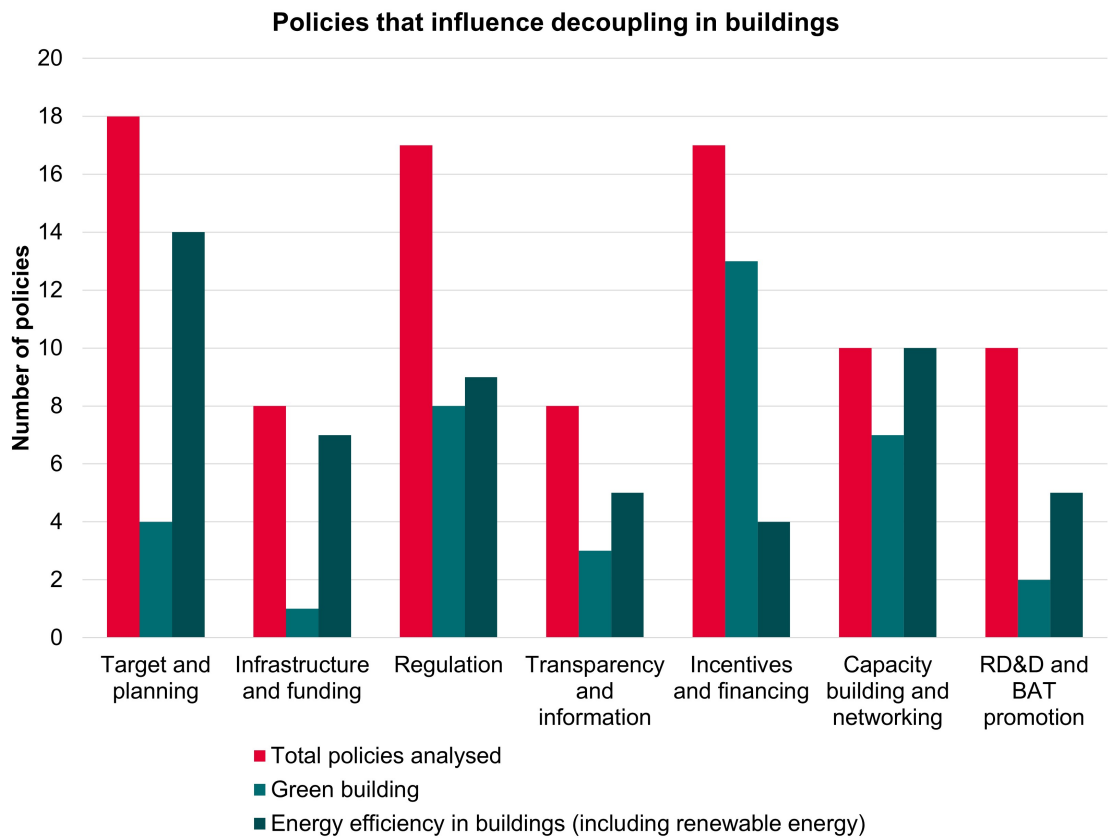


Figure 10: Policy analysis in green and energy efficient buildings.

Source: authors

### ***Critical gaps during construction phase***

Regulatory policies appear to be the front-runner when it comes to resources. For example, the sustainable sand mining management guidelines, Karnataka Sand Policy, 2011, and Fly Ash Notification (S.O. 763 (E)), have been commendable in placing restrictions on the extraction of soil and sand. However, despite a stringent legislation being in place, there continues to be a strong nexus between local politicians or people's representatives and contractors resulting in a situation that bypasses the law in the sand

mining sector<sup>4</sup>, resulting in illegal, indiscriminate sand mining (Pallavi & Gupta, 2013). On the other extreme the Andhra Pradesh state government has adopted a free sand policy to address this issue which has not improved this situation either (Department of Mines and Geology, 2016; Subba Rao, 2017). As an unintended consequence of making sand free, it has further resulted in the indiscriminate use of sand as a filling material in the place of C&D waste.

It is clear that regulations alone cannot bring the intended change especially in the absence of strict compliance and verification. A nodal agency similar to that of the BEE, a national policy similar to the energy conservation act and a consolidated policy framework similar to the O&M phase to facilitate decoupling is totally absent during the construction phase, especially for construction materials. The R&D institutes have made considerable progress in identifying innovative alternative technologies – both non-disruptive (efficient brick kilns such as vertical shaft brick kilns, hollow bricks) and disruptive technologies (fly-ash bricks, M-sand) and also overall low-energy/resource design. However, they often fail to enter the market due to lack of policies such as incentives, finance, capacity building, skill development initiatives and involvement of Small and Medium Enterprises (SMEs). This shows the importance of the missing link between innovation and market incubation of these technologies in the building sector. Further, there is a clear lack of transparency and information policies to ensure dissemination of these technologies.

### *Recommendations*

Based on the gap analysis [Table 4](#) shows key recommendations to promote decoupling

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<sup>4</sup> Some commentators have compared this to a mafia-like approach to circumvent the rules.



during construction phase in a consolidated way and are briefly explained below:

Table 4. Recommendations for decoupling during design and construction phase

	National	State	Local
<b>Target and Regulations</b>	<ul style="list-style-type: none"> <li>• Frame soil Management Guideline</li> <li>• Introduce Construction and Demolition code</li> <li>• Establish a central nodal agency for resource efficiency similar to that of the BEE</li> <li>• Introduce resource efficiency directive on the lines of energy conservation act as suggested by Niti Aayog (2017)</li> <li>• Prepare building construction sector specific targets for decoupling as a part of larger goals such as NDCs for Paris Agreement or SDGs.</li> </ul>	<ul style="list-style-type: none"> <li>• Adapt and adopt national level guidelines, codes and directives</li> <li>• Establish green building centres as nodal agencies at state level to act as knowledge –bank agency that promote R&amp;D, capacity building, and ensure policy compliance (e.g. Kerala State Nirmithi Kendras)</li> <li>• Update State schedule of rates to include alternative technologies and materials</li> </ul>	<ul style="list-style-type: none"> <li>• Encourage the use of alternative technologies and materials in government tendering documents</li> </ul>
<b>Market and incentives</b>	<ul style="list-style-type: none"> <li>• Create market for alternative technologies and materials</li> <li>• Promote sustainable public procurement policies</li> <li>• Resource efficient building materials made with recycled construction and demolition waste have to be standardized to promote greater linkage between their research and development and market acceptance</li> </ul>	<ul style="list-style-type: none"> <li>• Promote ‘deconstruction’ rather than ‘demolition’ of buildings</li> <li>• Provide financial assistance for the necessary technology upgradation</li> <li>• Promote SMEs in the manufacture of alternative technologies and materials</li> </ul>	<ul style="list-style-type: none"> <li>• Promote preferential procurement of alternative technologies and materials</li> <li>• Ensure recycle and reuse of C&amp;D waste and systemic deconstruction of buildings and the last option should be demolition.</li> </ul>
<b>Data and monitoring</b>	<ul style="list-style-type: none"> <li>• Establish a framework for accurate and reliable data procurement, and a stringent monitoring and evaluation mechanism.</li> <li>• Establish procedures for material flow accounting to measuring resource use and intensity, for example, as per the Sustainable Development Goals indicators 8.4.1 and 8.4.2</li> </ul>	<ul style="list-style-type: none"> <li>• Frame a robust measurement and evaluation framework for data collection and compliance</li> </ul>	<ul style="list-style-type: none"> <li>• Ensure proper data collection and compliance</li> </ul>

### ***Critical gaps during O&M phase***

O&M phase shows signs of weak decoupling, especially in non-residential buildings. Improvements in energy efficiency reduce the price of various energy conservation measures (ECMs) and would lead to economic growth by resulting in the uptake of such measures. However, they also carry a potential to reduce the effective price of energy, which often results in an increase in the energy consumption due to factors such as increased use of air-conditioning for thermal comfort, buying additional electrical appliances *etc.* which negates or significantly reduces the energy savings. This is called rebound effect. If the rebound effect turns out to be large it may undermine the rationale for policy measures to encourage energy efficiency (Sorrell & Dimitropoulos, 2008). It is absolutely crucial that energy cost savings derived from dedicated energy conservation and demand-side management (DSM) programmes translate into long-term bonds and are not converted into short-term monetary savings, which carries a risk of getting lost in the rebound effects.

Despite capital subsidies and feed-in tariff policies by state governments, the Comptroller and Auditor General (CAG) of India's report on renewable energy found that factors such as improper maintenance, technical challenges to grid connectivity, lack of net metering policy, provision of battery-less systems within the schemes discouraged domestic users, from taking advantage of their full benefits (CAG, 2015). Although the state of net metering policy has improved with majority of the states notifying a net metering policy, distortion in the tariff structure, and the lack of grid reliability are cited as severe impediments for the uptake of net metering policy (Kohli, 2017). Capital costs and performance risks, equitable distribution in high-rise buildings, inadequate quality standards, lack of labelling, and inclusion of a mandatory

requirement in local building bye-laws to provide SWH technologies have been cited as challenges to the expansion of SWH in residential buildings (Greentech Knowledge Solutions Pvt. Ltd, 2015).

### *Recommendations*

Based on the gap analysis Table 5 shows key recommendations to promote decoupling during O&M phase in a consolidated way.

**Table 5: Recommendations for decoupling during O&M phase**

	<b>National</b>	<b>State</b>	<b>Local</b>
<b>Target and Regulations</b>	<ul style="list-style-type: none"> <li>• Prepare quantifiable and time bound building construction sector specific targets for decoupling as a part of larger goals such as NDCs for Paris Agreement or SDGs</li> <li>• Prepare an energy efficiency code for residential buildings</li> <li>• Prepare a building typology/sub-sector specific technology mapping for non-disruptive and disruptive technologies</li> </ul>	<ul style="list-style-type: none"> <li>• Notify the energy conservation code for residential buildings</li> <li>• Eliminate distortions and cross subsidies in the tariff structure of net metering to reflect true cost of electricity</li> <li>• Devise financial / incentive / penal policy mechanisms that ensure the available energy is shared equitably and energy savings achieved due to concentrated policy framework are not lost in rebound effects.</li> </ul>	<ul style="list-style-type: none"> <li>• Ensure easy implementation and inspection of application of energy conservation building code</li> <li>• Promote net metering policy</li> </ul>
<b>Market and incentives</b>	<ul style="list-style-type: none"> <li>• Support investments in energy efficiency measures</li> <li>• Carryout capacity building of all actors to facilitate energy efficient building designs and demonstration activities</li> </ul>	<ul style="list-style-type: none"> <li>• Promote DSM programmes involving energy utility companies</li> <li>• Provide financial assistance for the necessary technology upgradation to mainstream efficient disruptive technologies</li> </ul>	<ul style="list-style-type: none"> <li>• Promote preferential procurement of alternative technologies in local tenders</li> </ul>
<b>Data and monitoring</b>	<ul style="list-style-type: none"> <li>• Establish a framework for data monitoring and acquisition to ensure the outlined targets are being met</li> <li>• Design policies to nudge green building rating systems and building</li> </ul>	<ul style="list-style-type: none"> <li>• Frame a robust measurement and evaluation framework for data collection and compliance through the State Designated Agencies</li> </ul>	<ul style="list-style-type: none"> <li>• Ensure proper data collection and compliance</li> </ul>

	owners to be forthcoming in sharing the building performance data <ul style="list-style-type: none"> <li>Identify areas with a high incidence of rebound effect to frame necessary policies to avoid rebound effect</li> </ul>		
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## Conclusions

In this paper the focus has been on understanding the impact and resource decoupling that has taken place through improvements to certain technologies, more efficient use of materials or disruptive change in the overall technology or material used. However, what these changes really highlight is the requirement of technological ‘leap-frogging’ to ensure decoupling, whether weak or strong. There is no doubt that India needs to develop new strategies so as to maintain human welfare with minimal damage to the environment. This means taking advantage of leap-frogging opportunities, such as minimizing waste through effective use of construction and demolition waste, fly ash etc. to produce a range of building products, passive building designs to improve energy efficiency in buildings, solar photovoltaics, and BEE-labelled electrical appliances etc. Moreover, changes across research and development, capacity building, policy, technology and finance are needed to ensure decoupling in the building construction sector.

A limitation of the study is the lack of analysis of use of the vital resource of fresh water and ground water contamination. This is to keep the scope of the study limited to understanding and analysing the concept of decoupling in the buildings sector. The findings from the study could be used to expand the research to other resources and environmental impacts beyond the ones analysed in this study.

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